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URBAN AIR SAMPLING BY HELICOPTER

R. H. McQuain, et al

Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio

1958

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A Progress Report

R. H. McQuain, J. M. Leavitt, R. C. Wanta and W. W. Frisbie
U. S. Weather Bureau

U. S. Department of Health, Education, and Welfare
Public Health Service
Robert A. Taft Sanitary Engineering Center
Community Air Pollution Program
Meteorology Section
Cincinnati, Ohio

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A Progress Report

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ABSTRACT

A method of measuring the concentration of oxidants in the vertical by using a helicopter is described. The helicopter can also be used to obtain the vertical temperature structure over an urban area concurrent with pollution sampling; in addition an estimation of the visible pollutants over a city and surrounding area can be obtained in a minimum of time.

URBAN AIR SAMPLING BY HELICOPTER

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A Progress Report

The sources of various atmospheric contaminants in most major cities have been fairly well established in recent years. The transport and dilution of pollutants over urban areas have also received considerable attention but the findings are inconclusive and often difficult to explain. One reason for this difficulty is that concentration of pollutants is dependent on meteorological influences which vary in the vertical as well as the horizontal.

Concurrent measurements of air pollutants and meteorological parameters have been restricted mainly to the lower 100 feet of the atmosphere. Some vertical measurements of air pollutants have been made using tall towers (television towers, skyscrapers, etc.) and captive balloons. Certain meteorological parameters (wind, temperature, and moisture) have been measured extensively using free and tethered balloons and tall towers. These methods of aerial measurement are not always suitable for obtaining a representative three dimensional profile of the air quality over an urban area. The tall tower has the disadvantage of set location and high cost of erection. The main drawback to the tethered balloon is its limited operational capability.

The helicopter provides certain advantages for the concurrent measurements of air quality and meteorological parameters. The

advantage of the helicopter over the fixed tower is its range, and it is more versatile than the tethered balloon due to greater lift and range, and the ability to reach greater heights.

To determine the feasibility of helicopter use for concomitant air quality and meteorological measurements, the Community Air Pollution Program of the Public Health Service is conducting a program of oxidant and temperature measurements in Cincinnati, Ohio, with the following main objectives:

1. To determine the air quality and meteorological sampling equipment best adapted to helicopter use;
2. To obtain concurrent air quality and meteorological measurements in the vertical over an urban area.

OPERATIONAL PROCEDURE

The helicopter was leased by the Public Health Service from Ohio Valley Airways and is available on request. First to be investigated were meteorological conditions favorable for high pollution concentrations(1), namely, slowly moving anticyclones, light winds in the lower troposphere, and stable lapse rates at or near the surface.

If there was a slowly moving anticyclone in the area with light winds in the lower few thousand feet of the atmosphere, an early morning flight was usually made to determine the temperature structure from the surface to 5000 feet at selected locations in the Greater Cincinnati area. The oxidant and temperature measuring flights were made subsequent to the early morning flights and

approximately at the time of solar noon to obtain as nearly as possible maximum oxidant concentrations. Seven temperature flights and 4 oxidant sampling flights, with concurrent temperature measurements, were made from July through October 1957.

TEMPERATURE MEASUREMENT METHOD

Air stability, determined from the vertical temperature profile is considered one of the major meteorological parameters affecting the dispersion of air pollutants. Air temperature is also a parameter that can be measured using a helicopter.

On the initial flight a standard Weather Bureau sling psychrometer was used to measure the temperature. These were taken by inserting the thermometer through a porthole of the helicopter and flying at constant altitude long enough for the instrument to reach ambient temperature. Three major limitations resulted from this method: (1) the readings were affected by the slipstream of the helicopter due to the position of the thermometer; (2) the unshielded thermometer was subjected to large radiational differences; (3) an undue amount of time was required for each reading due to the long time lag of the instrument. Because of these limitations, this method was abandoned after the first flight.

For all subsequent flights air temperature (wet and dry bulb) was measured by a Beckman and Whitley Assman-type phychrometer. This unit has a double radiation shield and is artifically aspirated. The temperature sensor consists of thermistor pairs in parallel, and the thermistors are checked for uniform operating characteristics.

The response time of this unit, 95% of steady state, is 6 seconds. The accuracy of calibrated temperature data is ± 0.1°F.

The thermistor unit was mounted on the step of the helicopter halfway between the skid and the cowling, a position approximately 10 feet below the rotor. The unit was connected to the indicator with four conductor cables having a standard resistance of 2 ohms and a maximum resistance of 20 ohms.

The modus operandi for each flight was to mount the sensing device pointing forward as the helicopter moved forward. A forward speed of 40 knots was maintained with sufficient time allowed at each level for the unit to reach ambient temperature. Dry and wet bulb temperature readings were taken at 100-foot intervals from the surface to approximately 5000 feet above ground; more detailed measurements were made in air layers of particular interest.

The readings in resistance units were converted to degrees Fahrenheit and the temperatures were then plotted as a function of height. The temperature profile for each flight is given in Figures 1 through 11.

AIR OXIDANT MEASUREMENT METHOD

Oxidant samples were taken at four levels on each flight. On the first flights a hand-cranked vacuum pump was used to draw the air sample through a midget impinger which was mounted on the instrument panel of the helicopter. The sampling equipment now consists of an electrically driven Gast vacuum pump that allows simultaneous measurements of sulfur dioxide, nitrogen dioxide, oxidants, and

particulate matter. The air intake was made of Tygon tubing which ran from the external opening at the forward edge of the right skid to the midget impinger. Oxidant samples were taken either while flying a small circle at constant elevation over a point or through a vertical layer on ascent or descent.

The impinger flask contained 10 milliliters of 1% potassium iodide solution buffered to PH7 using 0.1 molar $K_2HPO_4.7H_2O$ and 0.1 molar $KHPO_4$, which was the liquid adsorbing reagent. Ten-minute oxidant samples were collected at each sampling location with an air flow rate of 0.1 $ft.^3/min.$ which resulted in approximately 28 liters of air being sampled. Two milliliters of H_3PO_4 reagent saturated with sulfamic acid was added and mixed with the 10 milliliters of adsorbing reagent. This sample was then stoppered and allowed to stand for 5 to 10 minutes in a water bath at 72°F. A portion of this sample was then transferred to a Corex or fused silica cuvette and the adsorbance determined using a light source wavelength of 352 millimicrons. Using a standard curve the amount of oxidant present in the sample was determined. The amount of oxidant was converted to parts per hundred million (pphm) by volume. The accuracy of the data is within 10% of the reported values. Oxidant concentrations for the individual flights were plotted as a function of height (Figures 12-15).

VISUAL OBSERVATION METHOD

A written summary of the visual observations for each flight was prepared. Main emphasis was placed on the height of the top of visible pollution layers, lateral extent of visible pollution,

direction of pollution movement, and sources of dense smoke. The visual observations were occasionally supplemented by photography.

LOCATION OF SAMPLING PROBES

To obtain representative samples, both temperature and oxidant probes must be located outside the turbulence wake of the helicopter rotor-blades. Past studies[2] have indicated that under hovering or near hovering conditions, the turbulence wake extends vertically downward at least 60 feet along the full length of the rotor-blade. The sampling intake would have to extend forward at least 2 feet beyond the tip of the rotor[3] or to 60 feet or more below the rotor to be free of this effect.

The vertical extent of the turbulence wake below the rotor is reduced as the horizontal speed of the helicopter is increased. There is little induced air movement from the rotor beneath the forward portion of the fuselage at speeds from 44 to 60 miles/hour[4]. Therefore sampling was performed with the probes located beneath the forward portion of the fuselage and an air speed of approximately 40 knots. The results should be practically free of the influence of the helicopter.

FINDINGS

The measured ground concentration of oxidant on August 9, 1957 was 25 pphm in downtown Cincinnati and the air-borne concentrations of oxidants (Figure 12) on the same date ranged from 21 to 29 pphm. The ground oxidant concentration was the highest recorded value for the year on this date. Ground and aerial concentrations of oxidants

were of the same order of magnitude, indicating that the aerial sampling method was valid when the oxidant concentration was relatively high. Uniformity of measured ground and vertical concentration of oxidants on this date indicated that the atmosphere was fairly well mixed from the surface to 5000 feet. The temperature profile showed only shallow temperature inversions present in the lower 5000 feet of the atmosphere at the time of sampling. The three oxidant sampling flights subsequent to August 9 showed the highest concentrations in the lower 1000 feet with a marked decrease between 1000 and 2000 feet and fairly uniform distribution between 2000 and 5000 feet. There was also a summer to late autumn decrease at all levels which coincides with the behavior of oxidant concentrations measured near the surface.

The general slope of the concurrent raob* temperature profile at Dayton, Ohio showed fair agreement with the helicopter temperature profile, as shown in Figures 1, 3, 5, 7, 9, 10. However, as shown in Table 1, more than half of the cases showed a considerable difference in the height of the top of the nocturnal inversions at the two locations. The helicopter temperature profile showed small temperature striations which are not transmitted in the Weather Bureau raob report.

* A raob is a vertical profile of temperature obtained by an instrument that measures temperature, pressure, and moisture which is carried aloft by a balloon, and the data is transmitted by radio to the ground receiver.

The estimated height of the top of the visual pollution layers are compared to height of the top of temperature inversions in Figure 16. In most cases the temperature inversion top is above the height of the visible pollution. In the cases where the inversion top is below the top of the pollution an error in the visual estimate could be the explanation or the pollution may be exotic.

CONCLUSION

The vertical concentration of oxidants can be measured over any urban area using a helicopter. A slight modification of the sampling equipment now permits the measurement of additional pollutants, such as, SO_2, NO_2, and particulate material.

The temperature measuring equipment, due to its sensitivity and short time constant, is at present adequate to measure the temperature structure in the lower few thousand feet over a city.

The helicopter can be used to rapidly obtain the distribution of pollutants over a city.

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3. Gartrell, F. E., and Carpenter, S. B., 1955: "Aerial Sampling by Helicopter A Method of Study of Diffusion Patterns," Jour. of Meteorology, Vol. 12, pp. 215-219, June 1955.

4. Brotherhood, P., and Stewart, W., 1949: "An Experimental Investigation of the Flow Through a Helicopter in Forward Flight," Reprint (No. 2734), Aeronautical Research Council (London), 1952.

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Table 1

The height* of the top of the early morning nocturnal inversion at Dayton and Cincinnati.

Location	Dates					
	7/12/57	8/9/57	9/25/57	10/2/57	10/3/57	10/9/57
Cincinnati, Ohio	700	1050	1400	1350	1200	1100
Dayton, Ohio	700	1400	1300	400	1000	400

* All height given in feet above the ground.

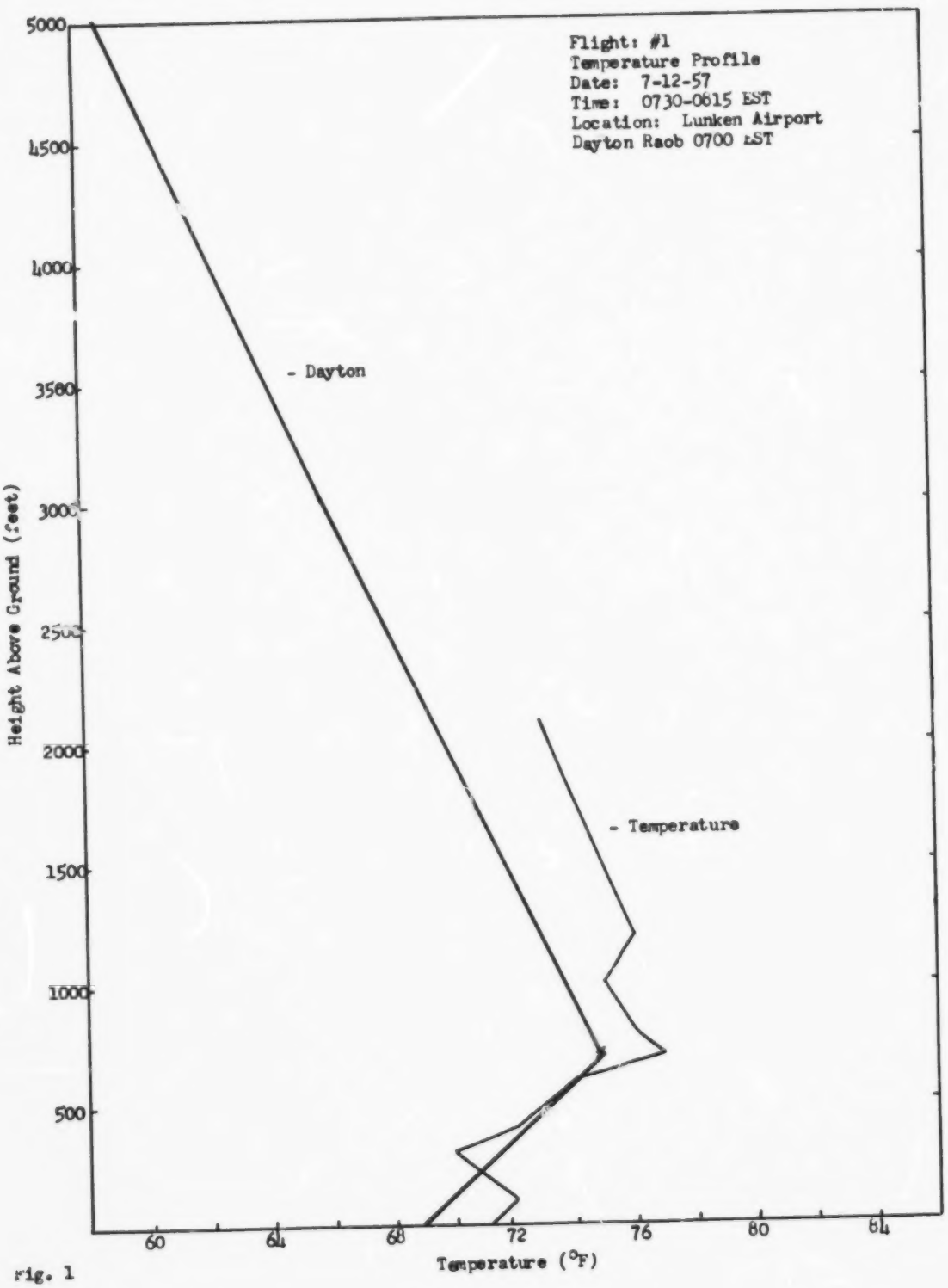
Flight: #1
Temperature Profile
Date: 7-12-57
Time: 0730-0815 EST
Location: Lunken Airport
Dayton Raob 0700 EST
- Dayton
- Temperature
Height Above Ground (feet)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
60
64
68
72
76
80
84
Temperature (°F)

Fig. 1

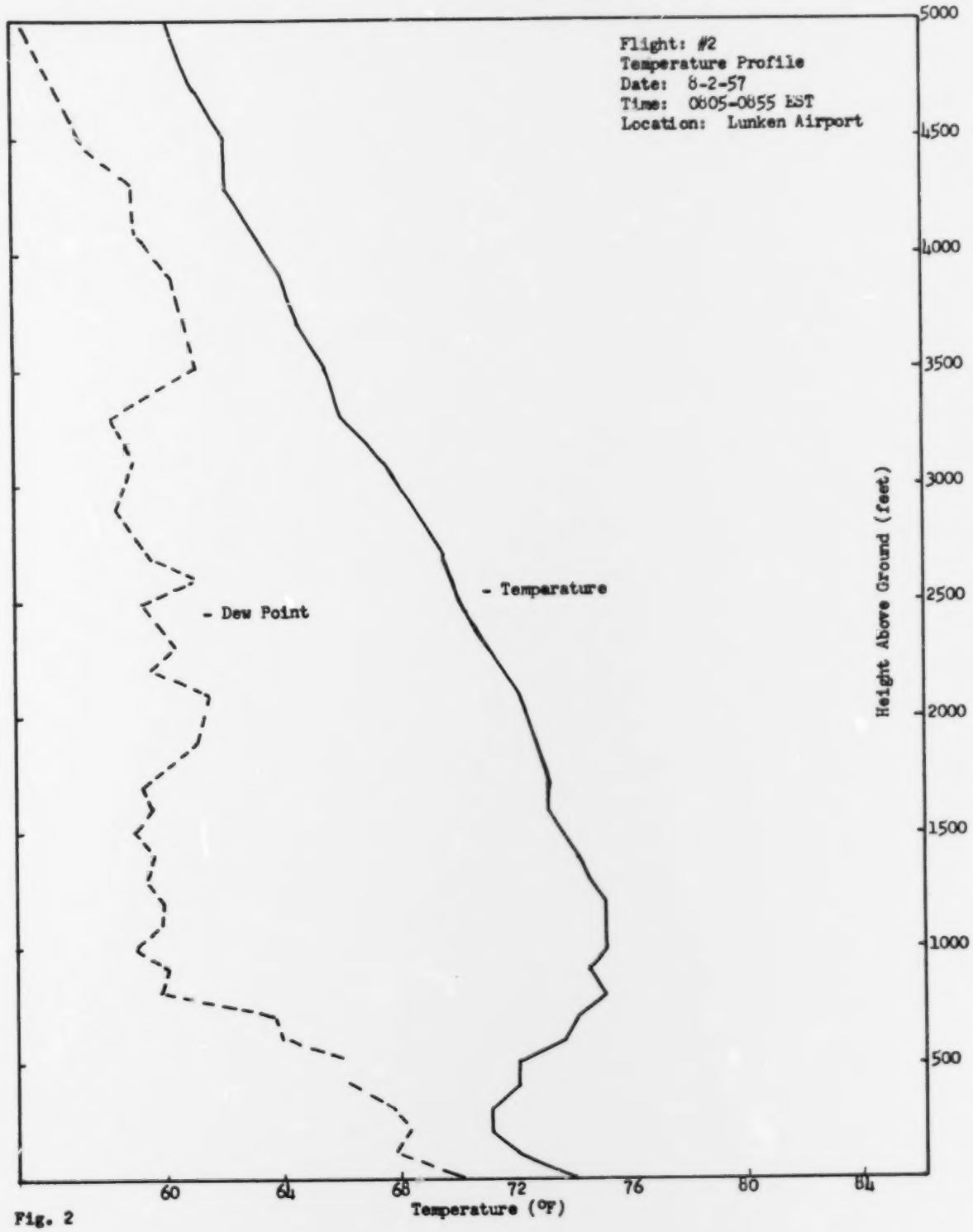
Flight: #2
Temperature Profile
Date: 8-2-57
Time: 0605-0655 EST
Location: Lunken Airport
- Temperature
- Dew Point
Height Above Ground (feet)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
60
64
68
72
76
80
84
Temperature (°F)

Fig. 2

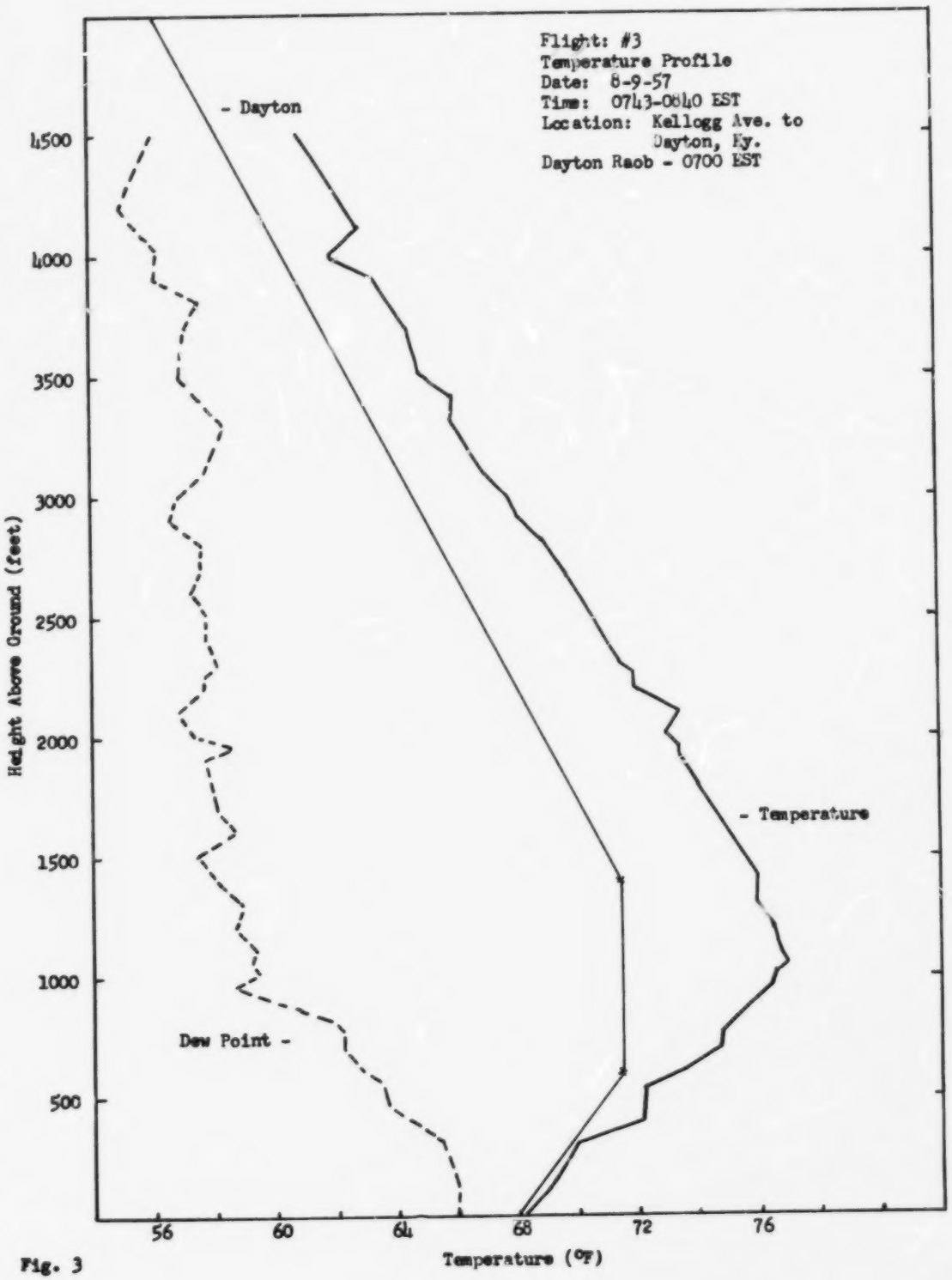
Flight: #3
Temperature Profile
Date: 8-9-57
Time: 0743-0840 EST
Location: Kellogg Ave. to
Dayton, Ky.
Dayton Raob - 0700 EST
- Dayton
- Temperature
Dew Point -
Height Above Ground (feet)
4500
4000
3500
3000
2500
2000
1500
1000
500
56
60
64
68
72
76
Temperature (°F)

Fig. 3

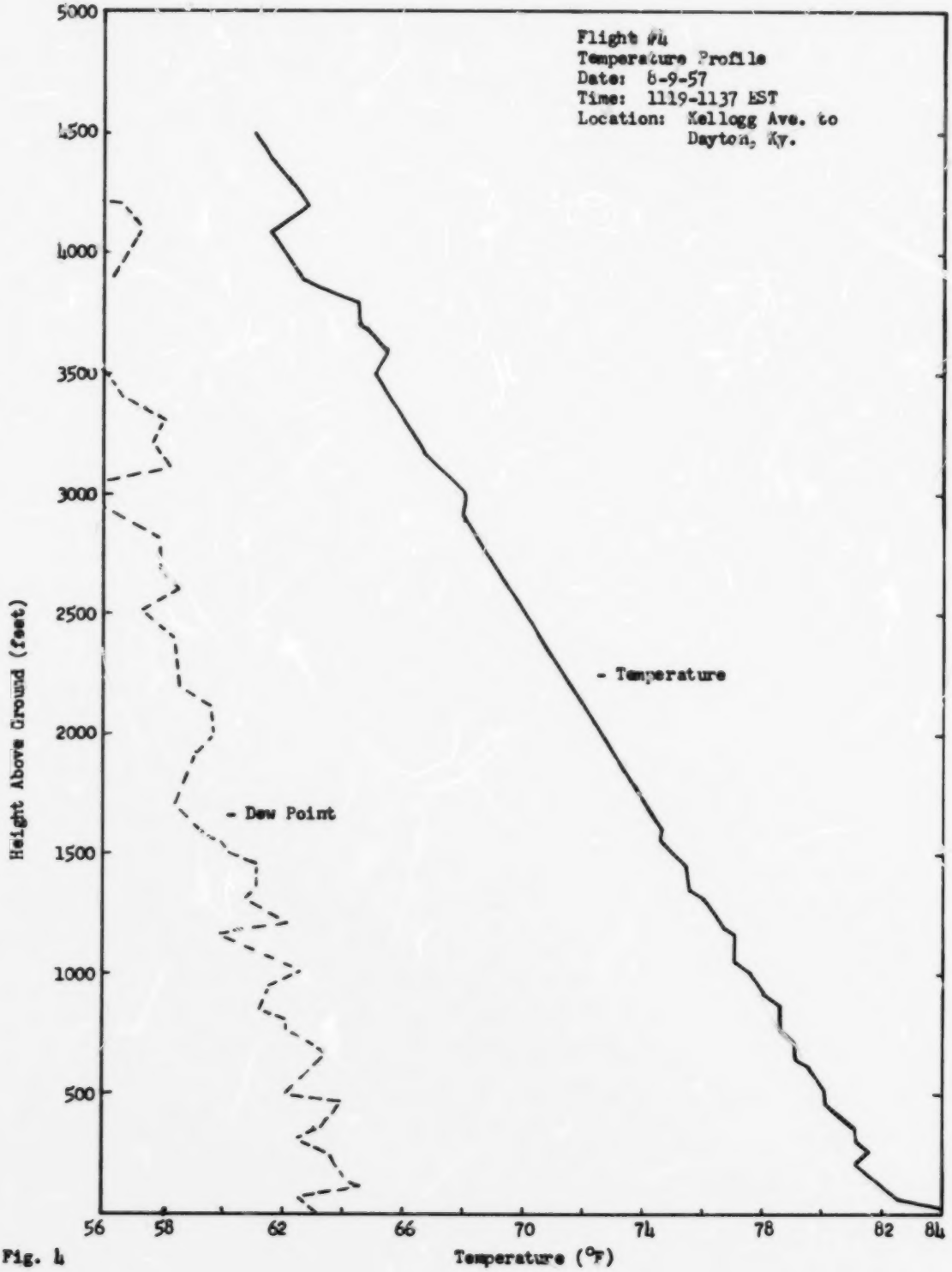
Flight #4
Temperature Profile
Date: 6-9-57
Time: 1119-1137 EST
Location: Kellogg Ave. to
Dayton, Ky.
- Temperature
- Dew Point
Height Above Ground (feet)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
56
58
62
66
70
74
78
82
84
Temperature (°F)

Fig. 4

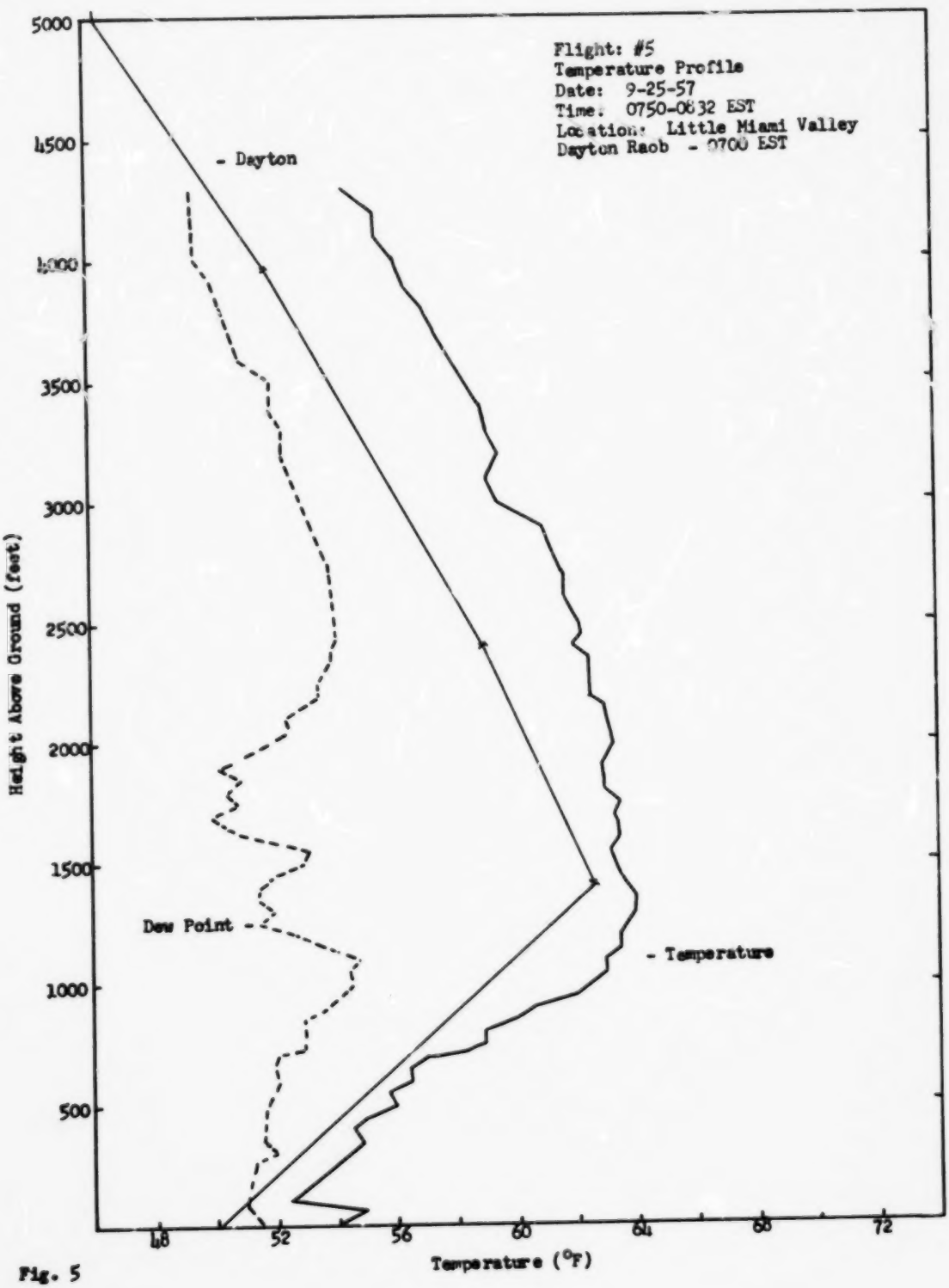
Flight: #5
Temperature Profile
Date: 9-25-57
Time: 0750-0832 EST
Location: Little Miami Valley
Dayton Raob - 0700 EST
- Dayton
Dew Point -
- Temperature
Height Above Ground (feet)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
48
52
56
60
64
68
72
Temperature (°F)

Fig. 5

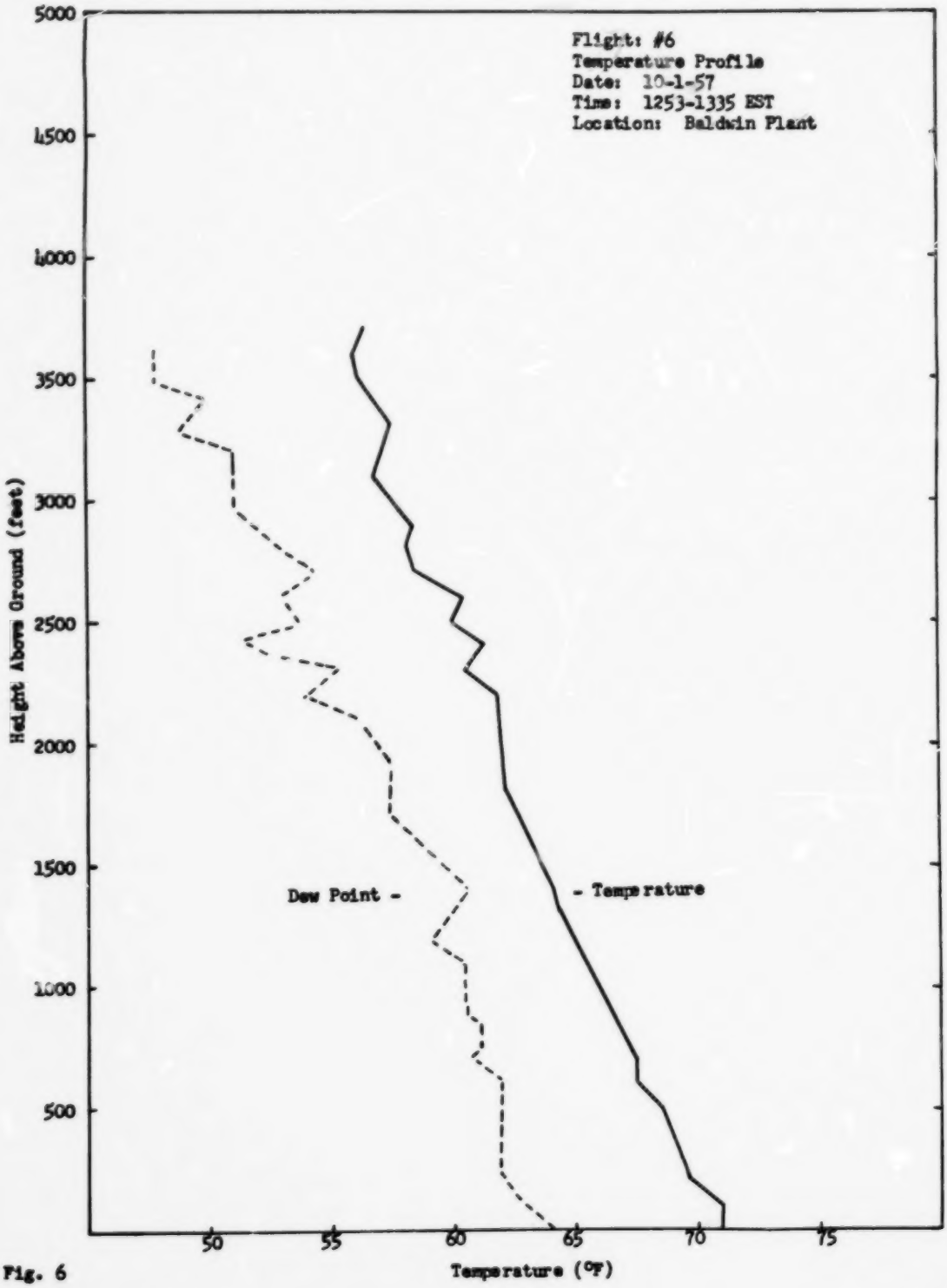
Flight: #6
Temperature Profile
Date: 10-1-57
Time: 1253-1335 EST
Location: Baldwin Plant
Height Above Ground (feet)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
Dew Point -
- Temperature
50
55
60
65
70
75
Temperature (°F)

Fig. 6

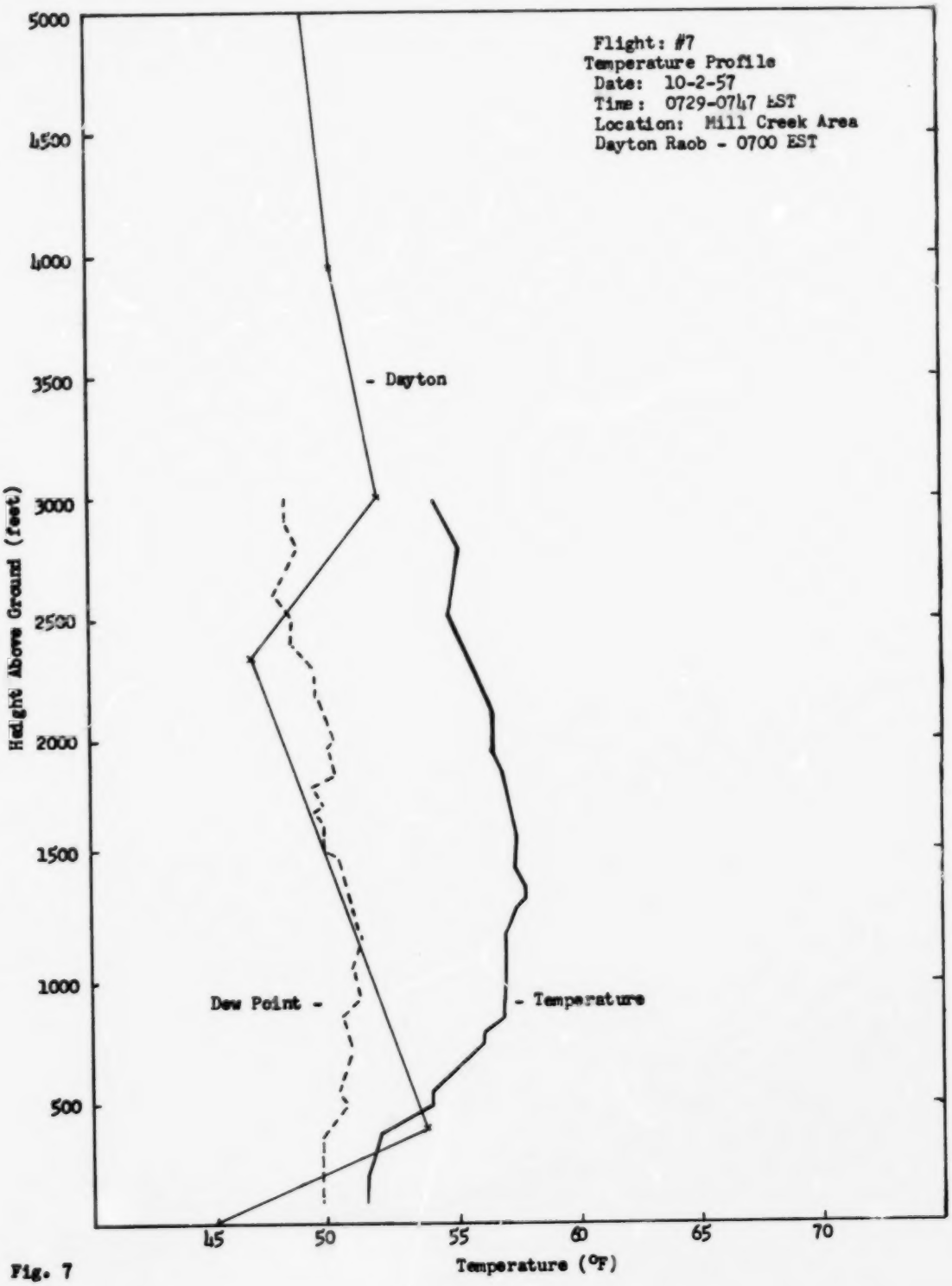
Flight: #7
Temperature Profile
Date: 10-2-57
Time: 0729-0747 EST
Location: Mill Creek Area
Dayton Raob - 0700 EST
- Dayton
Dew Point -
- Temperature
Height Above Ground (feet)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
45
50
55
60
65
70
Temperature (°F)

Fig. 7

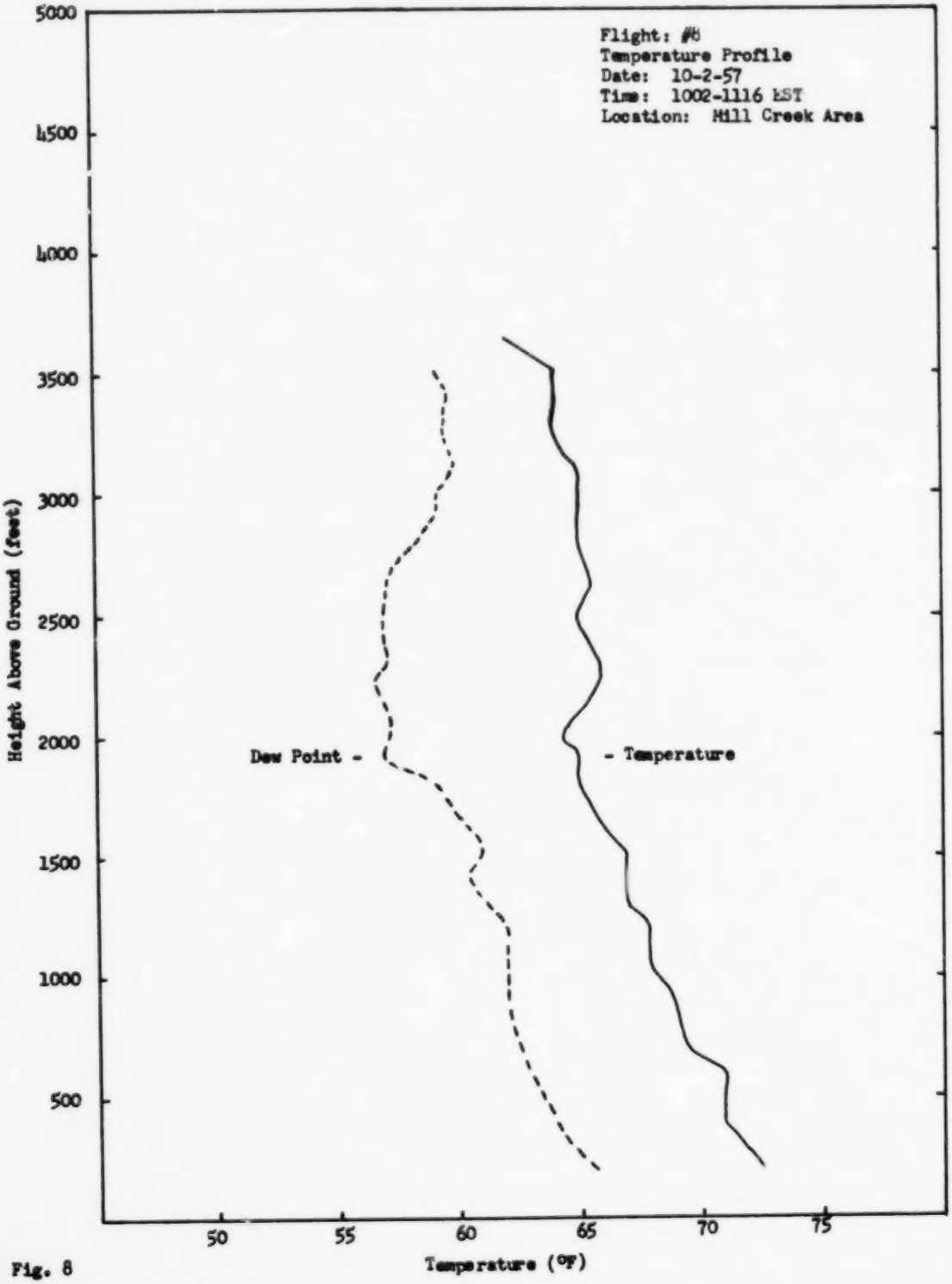
Flight: #8
Temperature Profile
Date: 10-2-57
Time: 1002-1116 EST
Location: Mill Creek Area
Height Above Ground (feet)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
Dew Point -
- Temperature
50
55
60
65
70
75
Temperature (°F)

Fig. 8

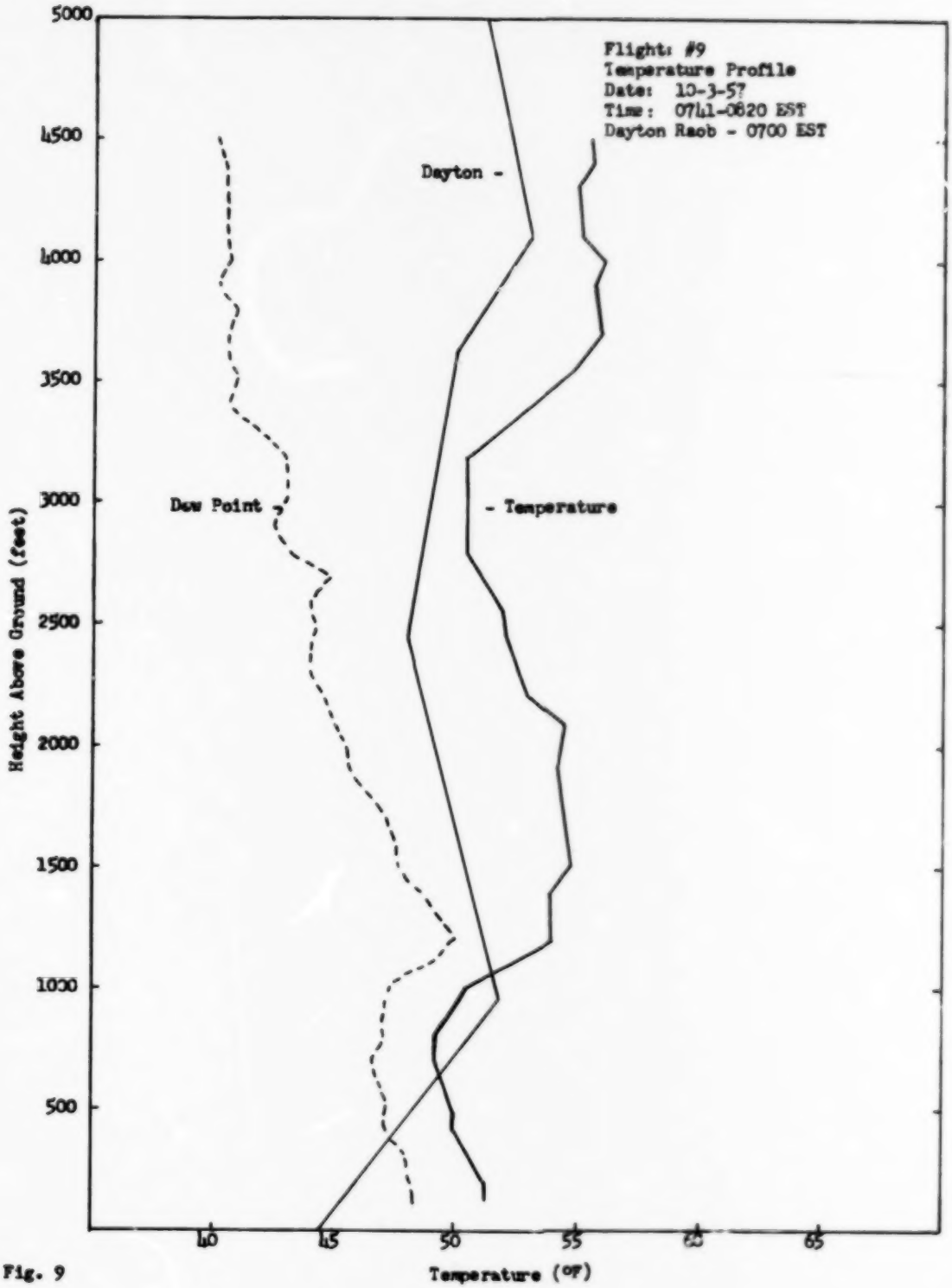
Flight: #9
Temperature Profile
Date: 10-3-57
Time: 0741-0820 EST
Dayton Raob - 0700 EST
Dayton -
Dew Point -
- Temperature
Height Above Ground (feet)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
40
45
50
55
60
65
Temperature (°F)

Fig. 9

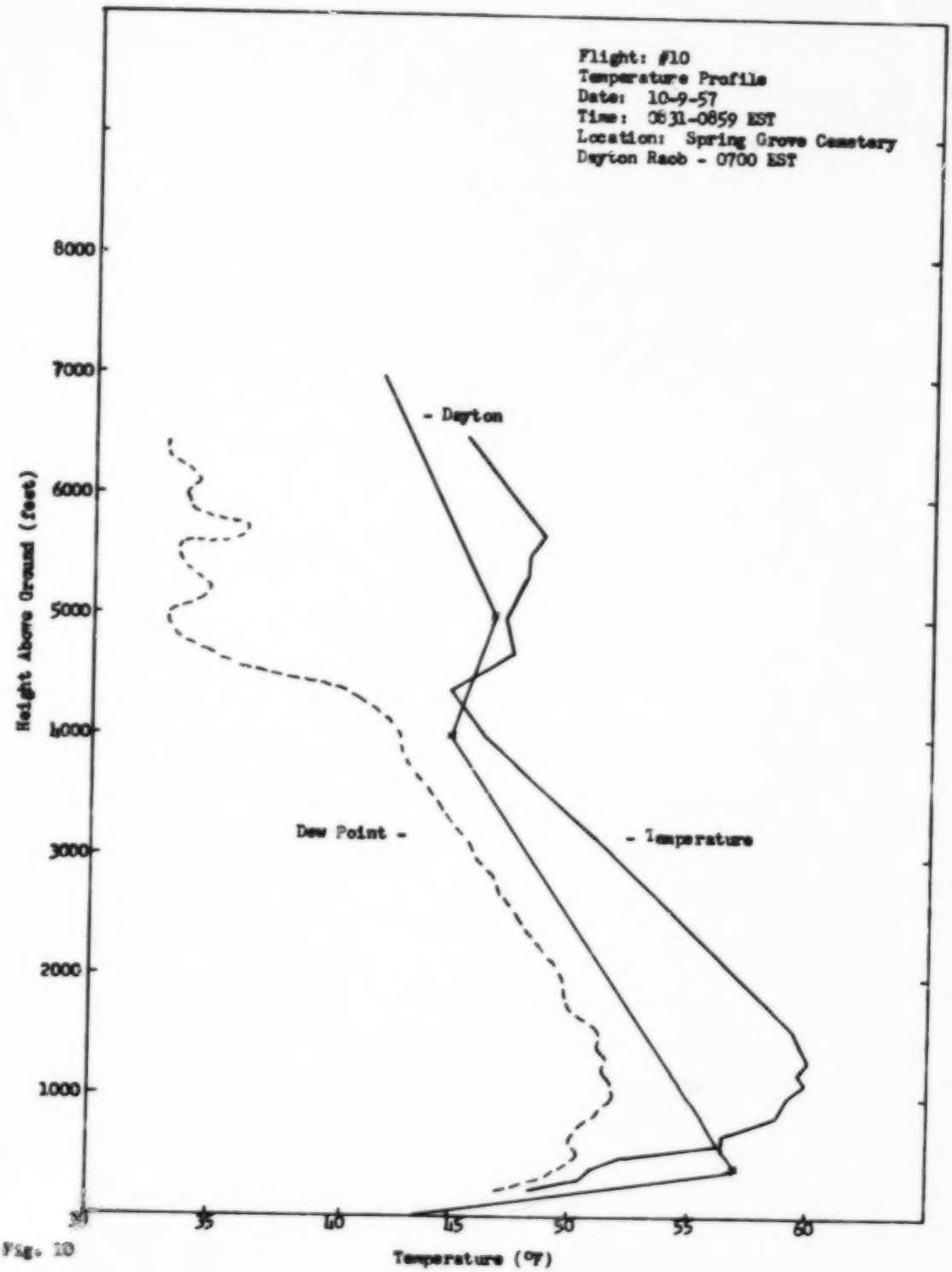
Flight: #10
Temperature Profile
Date: 10-9-57
Time: 0631-0859 EST
Location: Spring Grove Cemetery
Dayton Raob - 0700 EST
8000
7000
6000
5000
4000
3000
2000
1000
Height Above Ground (feet)
- Dayton
Dew Point -
- Temperature
35
40
45
50
55
60
Temperature (°F)

Fig. 10

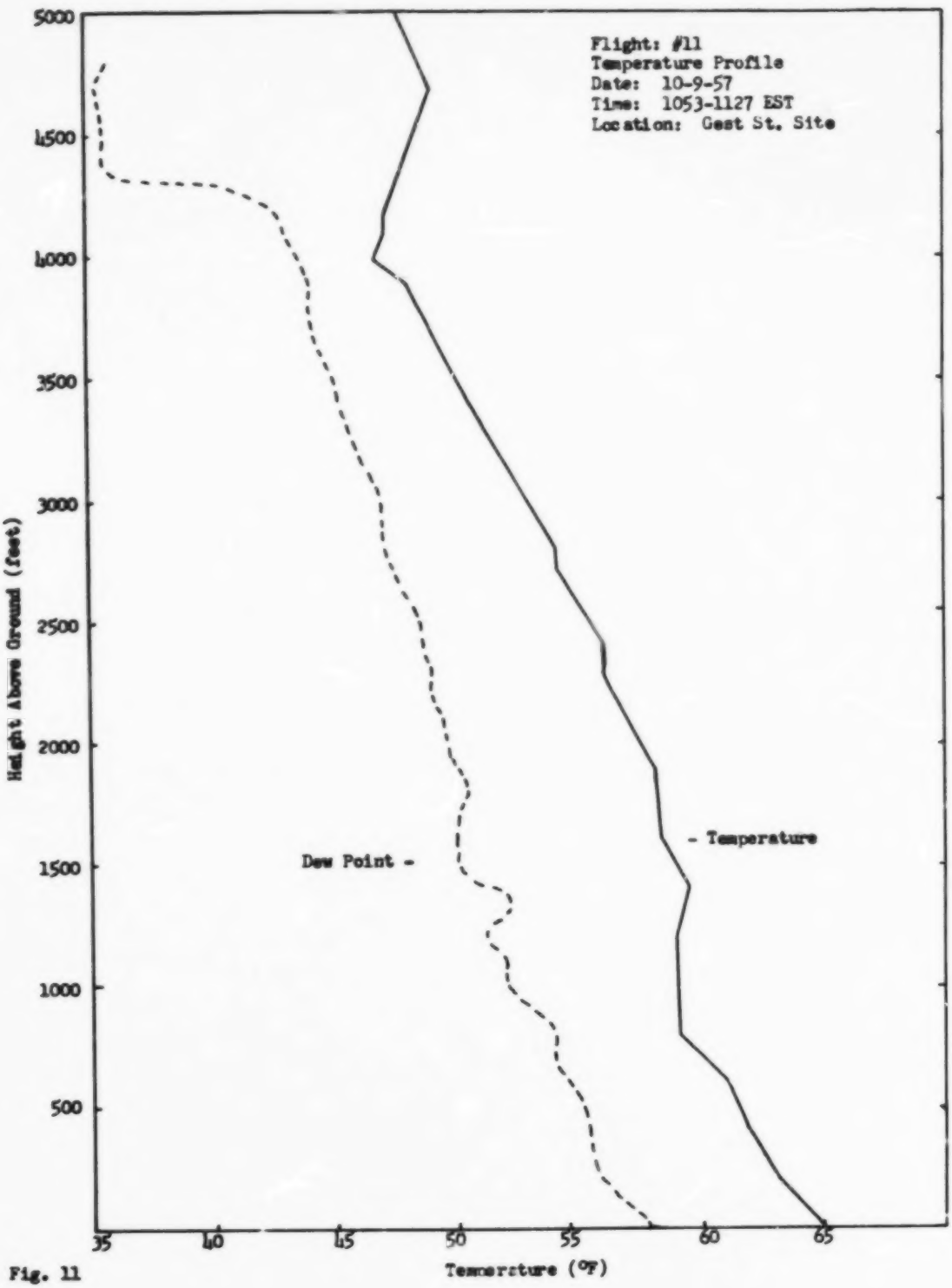
Flight: #11
Temperature Profile
Date: 10-9-57
Time: 1053-1127 EST
Location: Gest St. Site
Height Above Ground (feet)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
Dew Point -
- Temperature
35
40
45
50
55
60
65
Temperature (°F)

Fig. 11

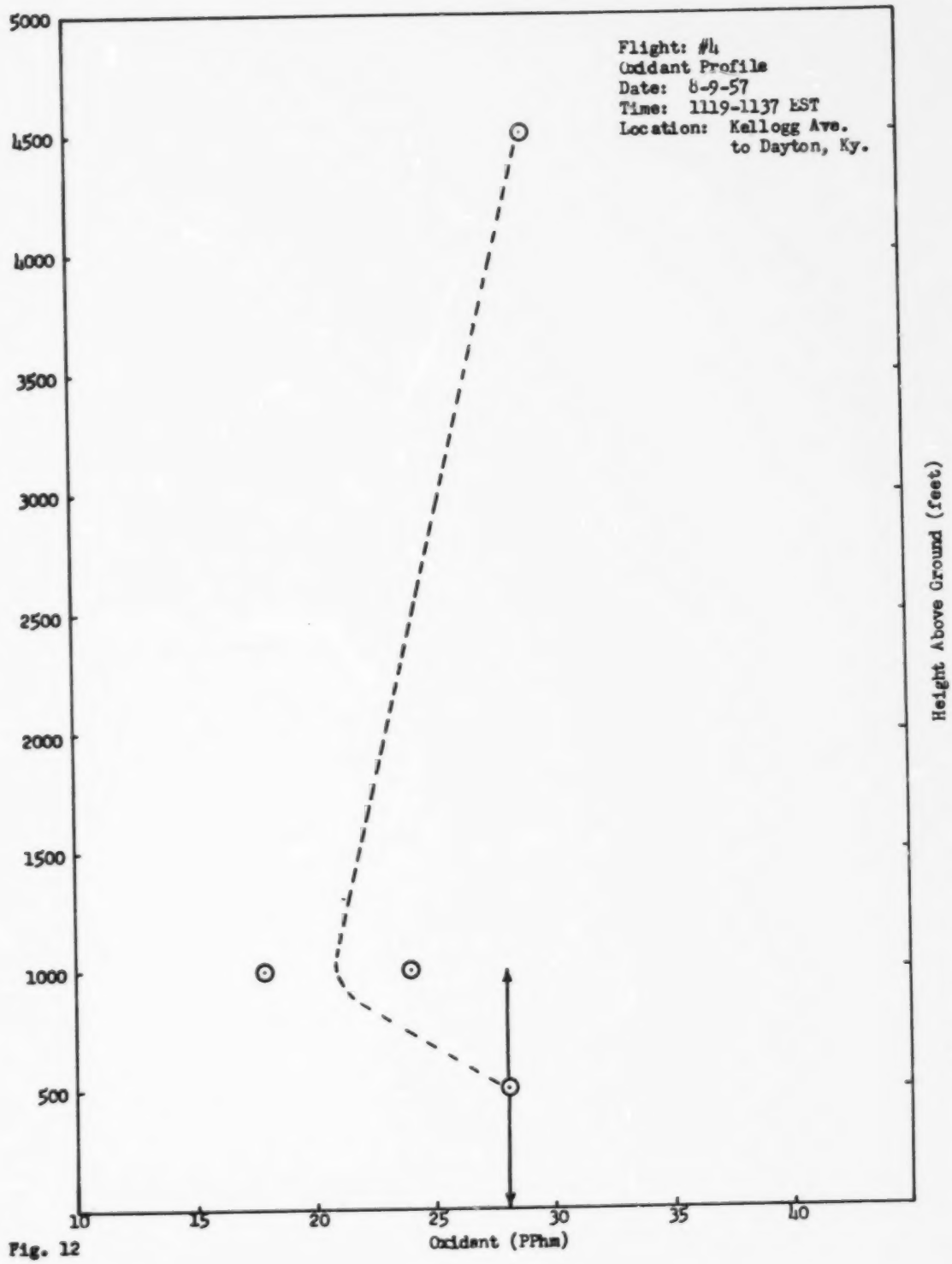
Flight: #4
Oxidant Profile
Date: 8-9-57
Time: 1119-1137 EST
Location: Kellogg Ave.
to Dayton, Ky.
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
10
15
20
25
30
35
40
Oxidant (PPhm)
Height Above Ground (feet)

Fig. 12

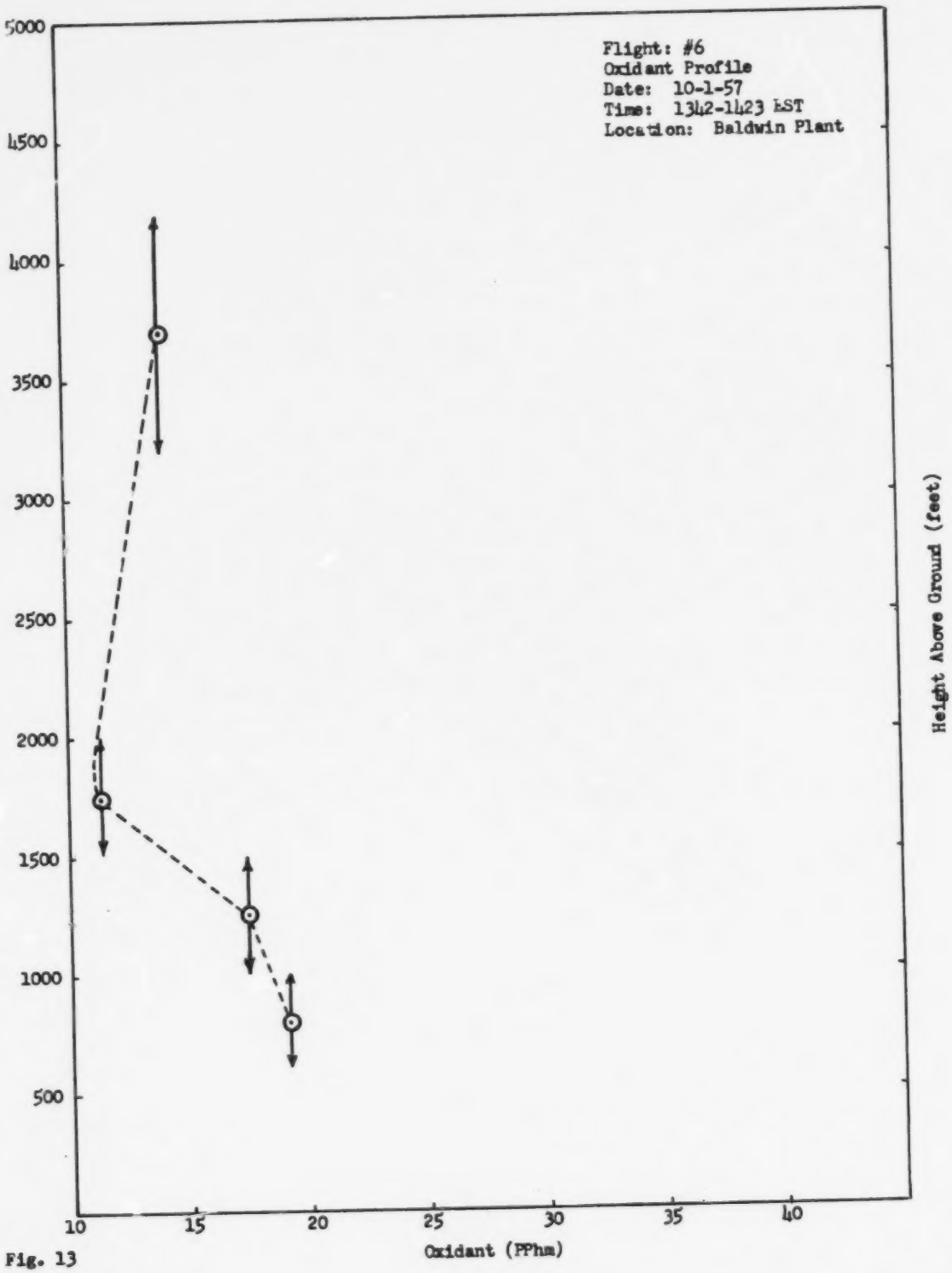
Flight: #6
Oxidant Profile
Date: 10-1-57
Time: 1342-1423 EST
Location: Baldwin Plant
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
10
15
20
25
30
35
40
Oxidant (PPhm)
Height Above Ground (feet)

Fig. 13

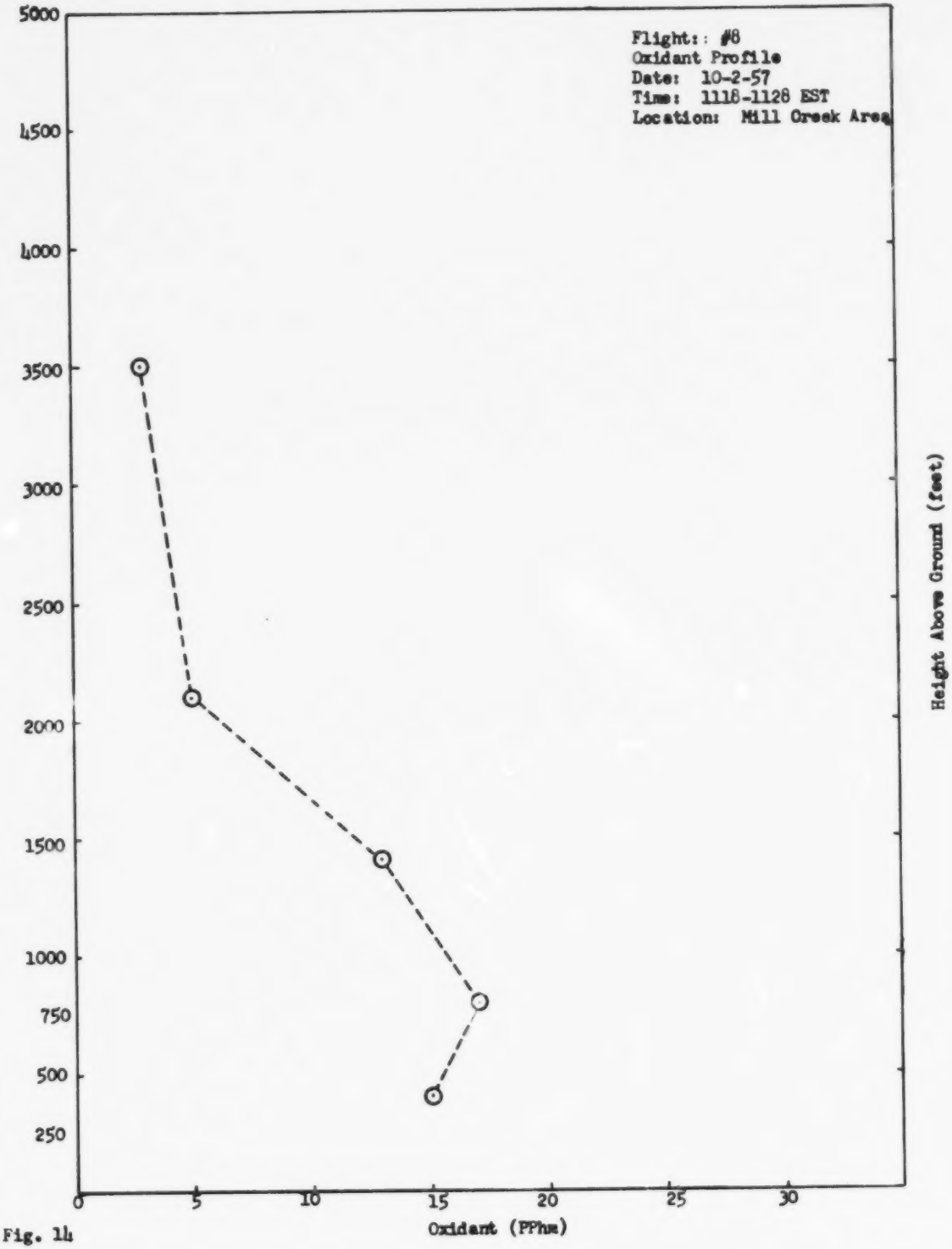
Flight:: #8
Oxidant Profile
Date: 10-2-57
Time: 1118-1128 EST
Location: Mill Creek Area
5000
4500
4000
3500
3000
2500
2000
1500
1000
750
500
250
0
5
10
15
20
25
30
Oxidant (PPhm)
Height Above Ground (feet)

Fig. 14

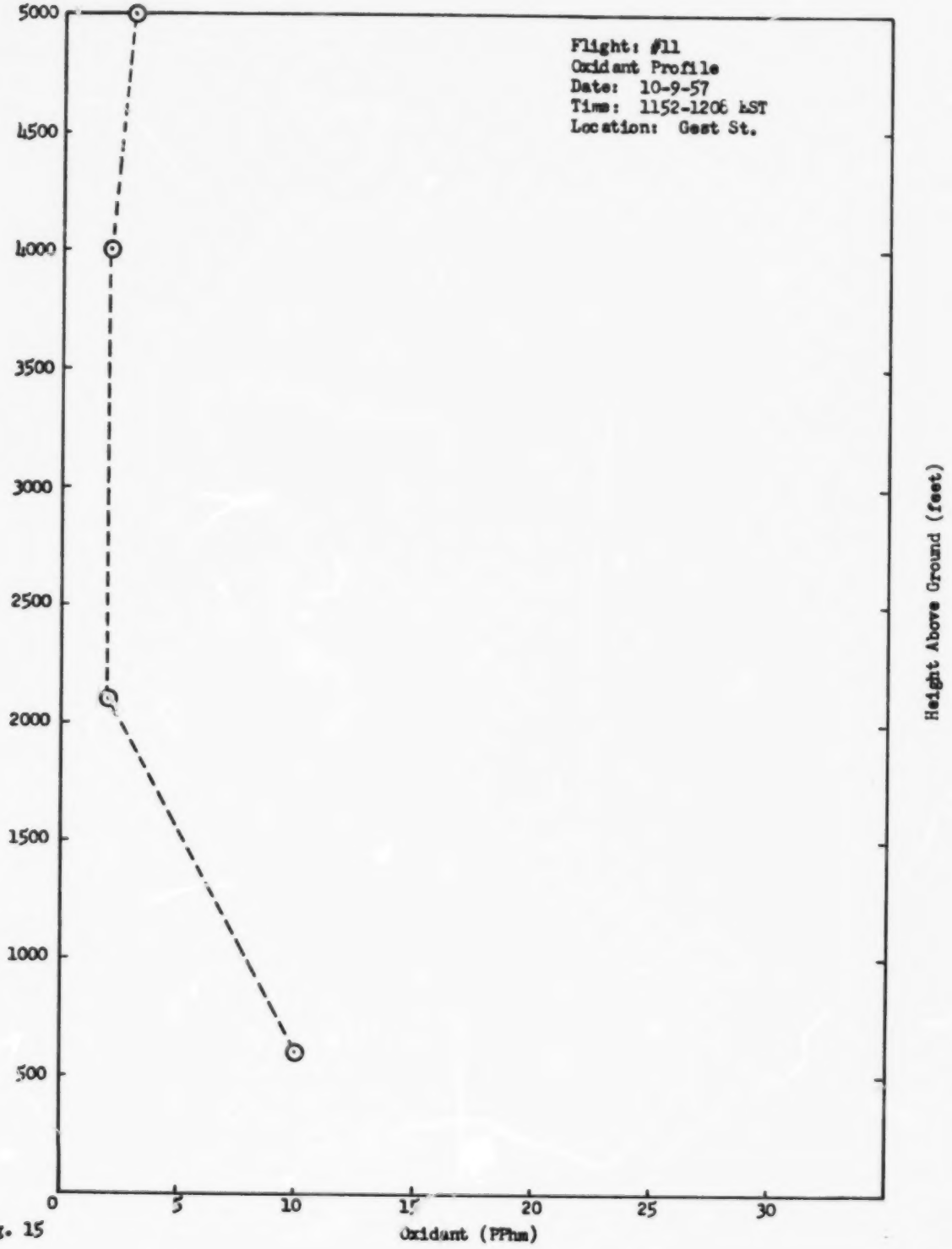
Flight: #11
Oxidant Profile
Date: 10-9-57
Time: 1152-1206 hST
Location: Gest St.
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
5
10
15
20
25
30
Height Above Ground (feet)
Oxidant (PPhm)

Fig. 15

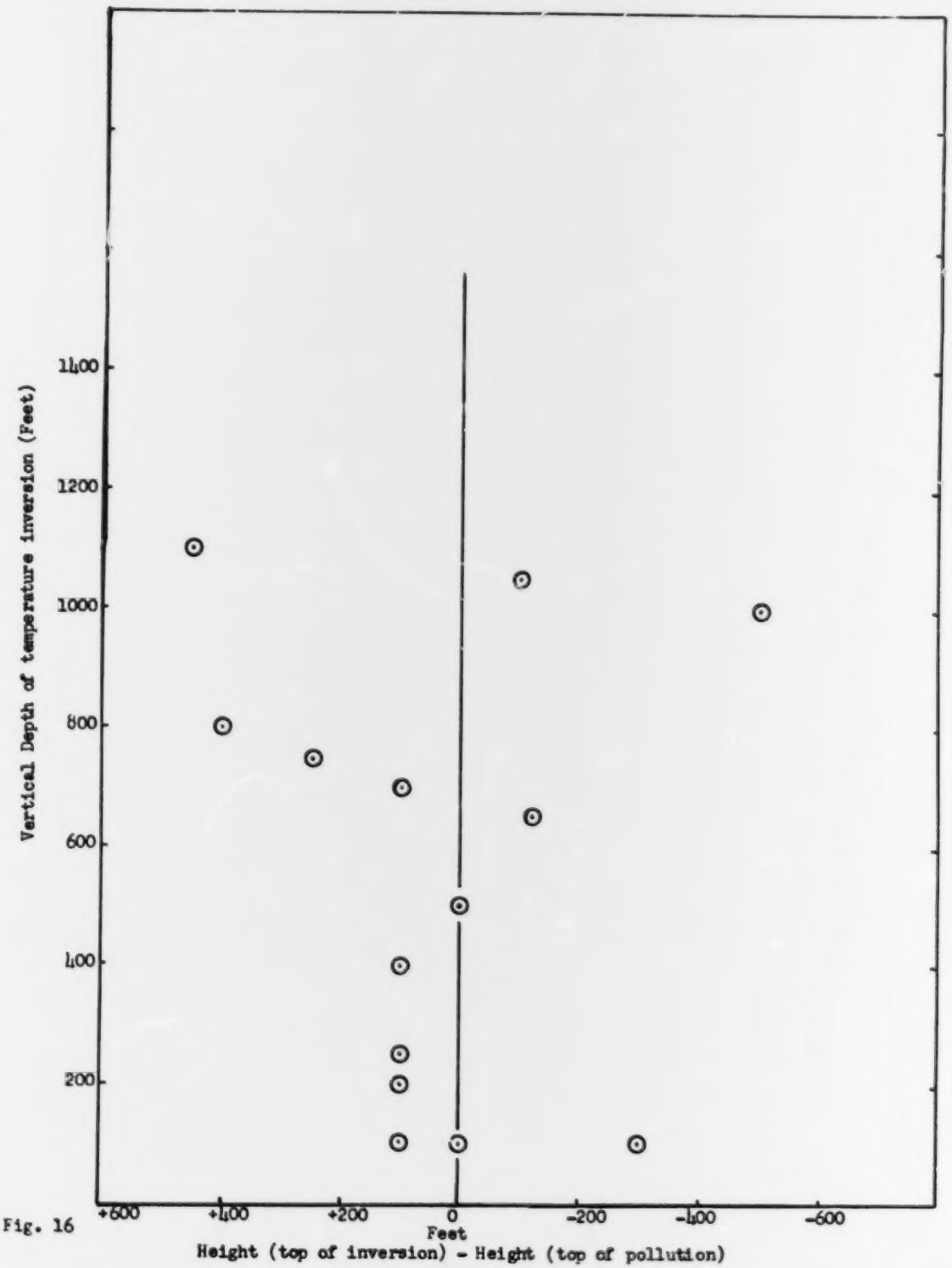
Vertical Depth of temperature inversion (Feet)
1400
1200
1000
800
600
400
200
+600
+400
+200
0
-200
-400
-600
Feet
Height (top of inversion) - Height (top of pollution)

Fig. 16